# Kinematic Analysis of a Track Link Mechanism for Trailing Edge Flaps of Aircraft

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***Abstract*** **- This paper presents the 3D kinematic analysis of the Track Link Mechanism for Trailing Edge Flaps of a Light Transport Aircraft (LTA). This complex mechanism comprises of 22 components and 9 joints that were modeled and assembled using CATIA software. The kinematic analysis of the mechanism was carried out using CATIA V4 Kinematics module, based on the initial layout proposed by the Wing Design Group in conjunction with Aerodynamics Group. The primary objective of this analysis was to minimize the lateral drift (≈ 1.37mm) in the roller movement as the roller moves in the track resulting a flap deflection of 0-30°. This necessitated changes in the geometry of the tracks (existing tracks are made of combination of a straight line and a curve) through which the roller moves. The paper puts forward in detail the existing mechanism and the new proposal with the modifications to the existing mechanism, carried out progressively to achieve the desired objectives and also presents the results thereof.**

***Keywords*** **- Kinematic Analysis; Joints; Lateral drift; Flap.**

## I. Introduction

The flaps are deployable surfaces used to alter the lift and drag characteristics during take off and landing of the aircraft [2]. The flaps are as shown in the Fig.1 below.

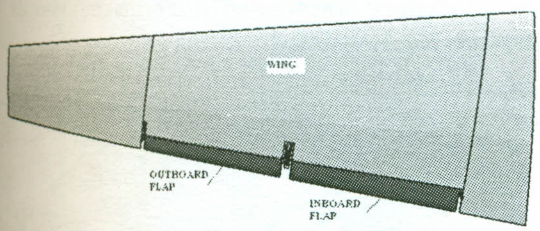


Fig 1. Flaps in aircraft wing

The flaps of an aircraft may be either simple hinged or split or single slotted or double slotted flaps [4] depending on the size of the aircraft or the maximum coefficient of Lift (CLmax) as shown in Fig. 2 below.

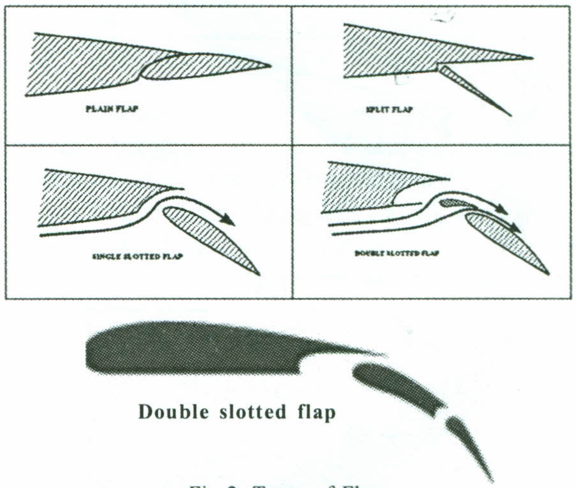


Fig 2. Types of Flaps

These flaps may be actuated either by electrical or hydraulic means. The Track-Link Mechanism for operating the flaps in general should be robust, simple in operation, easy to maintain and low weight, with no possibility of jamming or sticking during the operation and should be tolerant of deflections of wings and flaps due to air loads. It becomes difficult to design an optimum track-link mechanism if the trajectory of flap movement is "irregular" and involves fowler action.

Table I. Components of Track-Link Mechanism

| Sl.No | Part Description | Quantity |
|---|---|---|
| 1 | Flap | 02 |
| 2 | Track | 04 |
| 3 | Roller Assembly | 04 |
| 4 | Link | 03 |
| 5 | Cup | 02 |
| 6 | Linear Jack | 02 |
| 7 | Bracket | 04 |

This paper emphasizes on the kinematic design and analysis of the Track-Link Mechanism for operating the Trailing edge flaps of a typical light transport aircraft. The flap assembly forms one of the critical subassemblies in the main wing assembly. The subassembly consists of the following components (as shown in Table.1) and the schematic is as shown in Fig.3.

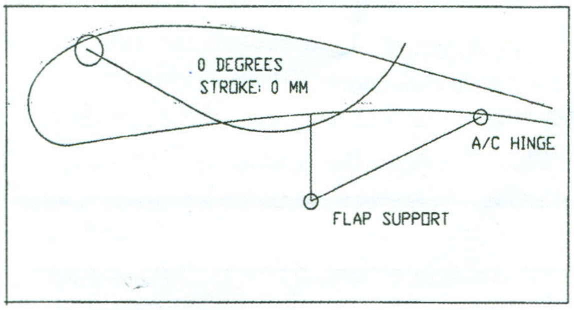


Fig 3. Schematic of Track-Link Mechanism

The LTA flaps discussed here are single slotted and split span wise into inboard and outboard flaps as shown in Fig.1. In the present investigation, the two flaps are actuated by a single electrical motor through two separate linear jacks connected to inboard and outboard flaps as shown in Fig. 4.

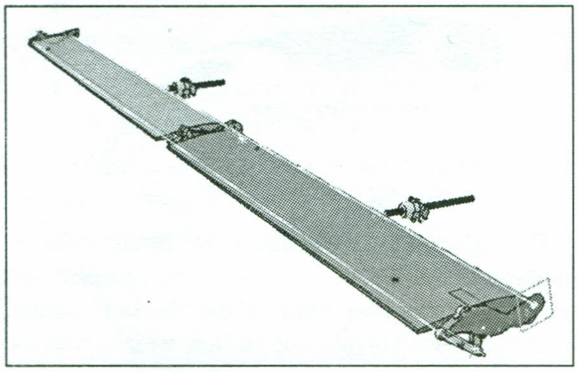

Fig 4. Track-Link Mechanism Layout

Each flap segment is supported by a track on either side. The tracks are fixed to the wing structure so that they are used as guides for the effective movement of the flap. On operation of the jack, the inboard and outboard flaps (LH & RH) are deflected from 0o to 30o in accordance with the guided roller movement along the flap tracks for the given jack stroke.

The kinematic study is carried out in order to ascertain the satisfactory working of the mechanism.

## II. Kinematic Design - Saras: A Case Study

The kinematic analysis was carried out using CATIA v4 kinematics module based on the initial layout proposed by the Wing Design Group. The kinematic analysis includes five CATIA sets, one kinematic set, and nine kinematic joints as shown in Table 2 and Fig.5.

Table II. Details of Kinematic Sets

| Set No. | Name of the set | Components |
|---|---|---|
| 1 | Flap | Flaps, Flap support lever, Roller assembly, Roller axis. Jack Attachment point. |
| 2 | Fixed | Flap Tracks, Jack hinge, Cone Axis. |
| 3 | Link | All the 3 links connecting cone axis and Flap support axis. |
| 4 | P1 | Jack rod attachment to flap. |
| 5 | C1 | Jack rod attachment to jack hinge. |

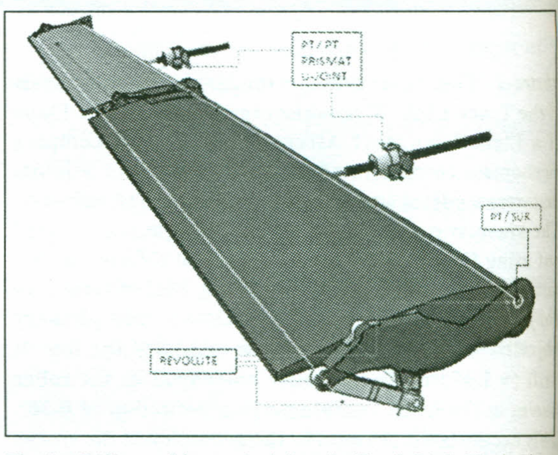

Fig 5. Different kinematic joints in Track-Link Mechanism

### A. Existing Mechanism

Fig. 6 shows the existing track (combination of straight line and arc) with roller assembly and link combination, with a maximum flap deflection of 40°.

Detailed study of the existing mechanism showed that the trajectory of the flap movement is highly irregular or non-linear. The trajectory was finalized based on iterative method as no parametric study was possible. Also, due to geometric constraints of the wing, any point on the flap moves on a conical surface. This necessitated accurate definition of the span wise axes namely cone axis, flap support axis and roller axis for satisfactory functioning of the mechanism as shown in Fig. 7.

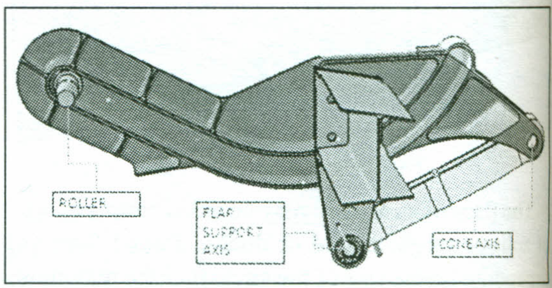


Fig 6. Existing Track with roller and link

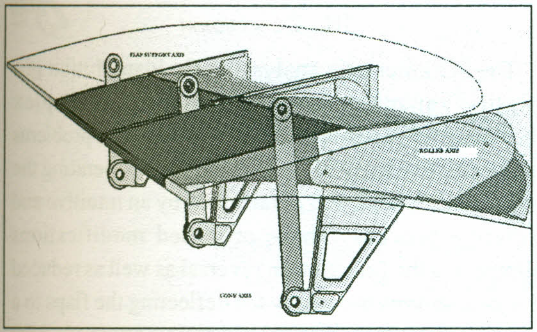

Fig 7. Details of the 3 – Axes of Mechanism

During its deflection from 0° to 40°, it was noticed that there is a lateral drift (towards inboard) of the roller by about 1.3 mm at around 20° flap deflection position as shown in Table 3. Also, the link motion direction was getting reversed around 20° of flap deflection, giving rise to a possible jamming or sticking of the flap movement as shown in Fig.8. It was further noticed that the actuator force necessary for the flap deflection was high.

Table III. Roller Drift vs Jack stroke

| Jack Stroke in mm | Roller Drift in mm |
|---|---|
| 0 | 0 |
| 40 | 0.62 |
| 80 | 1.0 |
| 120 | 1.22 |
| 160 | 1.302 |
| 200 | 1.23 |
| 240 | 0.956 |
| 280 | 0.355 |
| 300 | 0.08 |

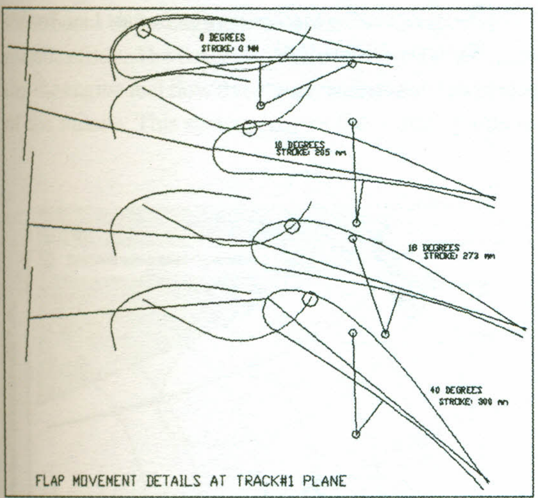


Fig 8. Details showing Link Motion Reversal

*B. Need For Modification*

It is not desirable to have lateral drift of the roller, high actuator forces and possibility of jamming or sticking during operation.

*C. Proposed Modification*

The proposed modification for the track link mechanism is as shown in Fig.9. As mentioned earlier, iterative method was used to obtain the trajectory of the flap movement. The kinematic analysis of the modified arrangement revealed that defining the cone axis below the flap and flap support axis above the flap eliminates the problem of jamming as shown in Fig. 10. The shape of the track was a straight line instead of a combination of a line and a curve Fig. 9.

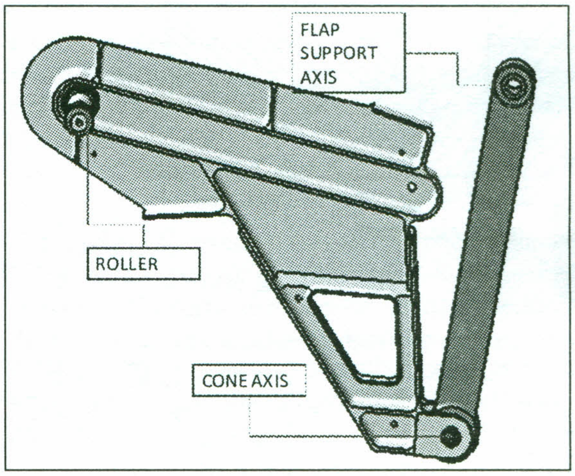


Fig 9. Proposed Modification

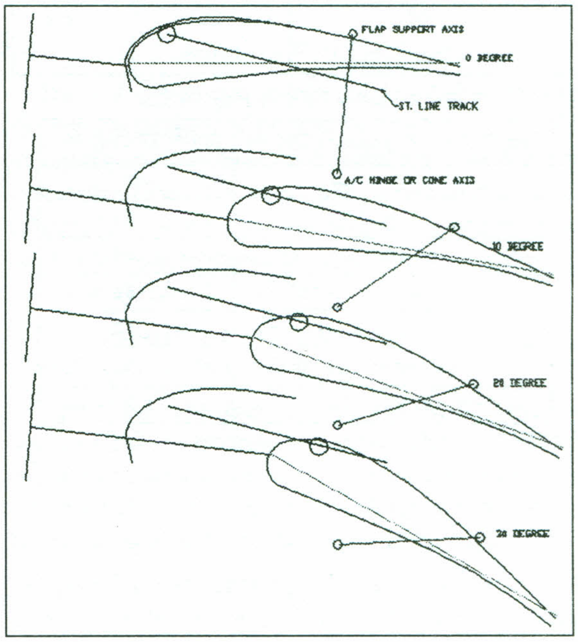


Fig 10. Link Motion Reversal Eliminated

Also, it was found that with the above modification, the jack strokes necessary for deflection of flaps reduced drastically as shown in Table. 4.

The lateral drift noticed is shown schematically in Fig. 11 and its noted variation for every 5° of flap deflection is given in the Table 5. It was found that the lateral drift could not be reduced.

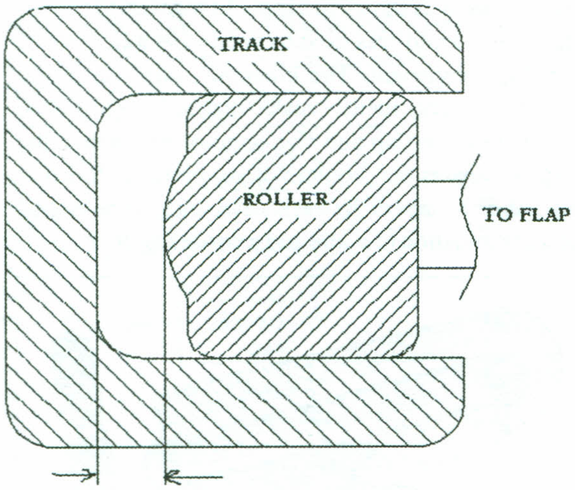


Fig 11. Lateral Drift

Table IV. Flap Deflection vs Jack Stroke

| Flap Deflection in Degree | Jack Stroke in mm | |
|---|---|---|
| | Existing | St.line |
| 0° | 0 | 0 |
| 10° | 205 | 145.2 |
| 20° | 277.5 | 185.4 |
| 30° | 291 | 215.1 |
| 40° | 300 | -- |

Table V. Roller Drift vs Flap Deflection

| Flap Deflection Angle in Degree | Roller Drift in mm |
|---|---|
| 0 | 0 |
| 5 | 1.53 |
| 10 | 1.63 |
| 15 | 1.61 |
| 20 | 1.53 |
| 25 | 1.41 |
| 30 | 1.27 |

## III. Conclusion

The 3D kinematic analysis of the Flap Motion in a Light Transport Aircraft involves a complex mechanism. The solution to the encountered problems in the existing track-link mechanism for operating the trailing edge flaps was determined by an intuitive and iterative process. These proposed modifications eliminated the link motion reversal as well as reduced the jack strokes necessary for deflecting the flaps to a particular angle during operation as compared to the existing mechanism.

However, the lateral drift of the roller inside the track could not be avoided. With all the above modifications, it was ensured virtually through CATIA v4 Kinematics module that the proposed Track Link Mechanism works properly in the desired manner. Also, the in-plane motion of the flap and the system behavior is being studied in a specially designed cruise test rig.

## Acknowledgement

We thank Head, C-CADD, Project Director, SARAS, and all the C-CADD staff for their encouragement and timely support provided during the execution of this project.

## References

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